CLIMATE CHANGE REGULATIONS

MODELING ECONOMIC IMPACTS

1. BACKGROUND

Assembly Bill 1493 (Pavley) calls on the California Air Resources Board (ARB) to develop and adopt regulations that achieve the maximum feasible and cost-effective reduction of climate change emissions from California's non-commercial motor vehicles, beginning with model year 2009.

This document outlines the ARB's approach to evaluating the economic impact of regulations designed to implement AB 1493. The ARB encourages comments and suggestions from stakeholders regarding the tools and methods presented here and in related workshops. In addition, a team of peer reviewers from the University of California has been contracted to ensure that the tools and methods used in our analysis represent the best science.

The ARB has contracted with the Institute of Transportation Studies at the University of California, Davis to develop a consumer response model (CARBITS). CARBITS will simulate the purchasing behavior of consumers in response to changes in attributes, such as vehicle price, due to climate change regulations.

Automakers are expected to incur incremental costs as they integrate new equipment and design features to comply with climate change emission standards. While some compliance costs may be absorbed as routine expenditures on new product development, automakers may choose to pass the balance of these costs along to new-car buyers in the form of higher sticker prices. But new vehicles may also yield substantial reductions in operating costs due to the strategies that automakers employ to meet the climate change emission standards.

In addition to evaluating purchasing behavior, the ARB will be working with experts to evaluate the so-called "rebound effect", according to which drivers will tend to "spend" some of their savings from reduced operating costs by driving more. To the extent that climate change regulations result in reduced operating costs, there may be a rebound effect.

The outcomes of the ARB's consumer response modeling and the rebound analysis will in turn shape the scenarios simulated by a macroeconomic model to estimate the impact of climate change regulations on the State's economy as a whole. (See Figure 1 below.) The ARB will use a computable general equilibrium model to estimate climate change regulation impacts on State output, personal income, and employment.

In parallel with its economic impact analysis, ARB is developing the climate change emission standards as well as per-vehicle cost estimates for the equipment changes available to automakers to comply with the standard. These factors, together with the degree of compliance flexibility available to automakers through early credits and alternative compliance protocols, will affect ARB's estimates of the economic impact of the regulations, both for individual automobile owners and for the State of California. A staff report containing findings in all these areas will be issued in the summer of 2004.

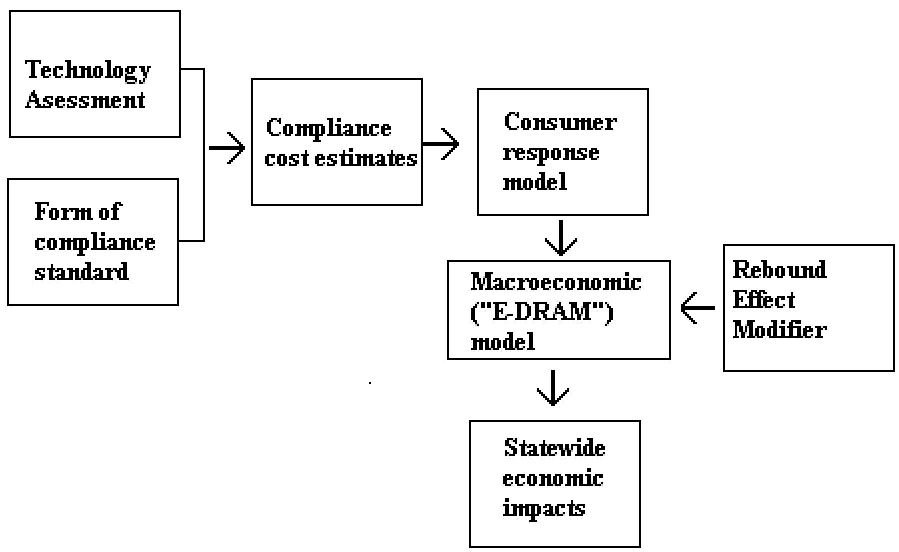


Figure 1. Economic Analysis Flow Chart

This analysis of climate change regulations focuses primarily on evaluating how the cost of complying with proposed regulations will affect ownership and operation of non-commercial vehicles, and how those changes, in turn, will impact the State's economy.

The ARB's economic analysis will contribute to development of the climate change regulations, which are due to the Legislature for review no later than January 1, 2005. The regulations would take effect January 1, 2006, and would apply to vehicles manufactured for model year 2009 or later.

In addition to its prospective economic modeling, the ARB is working with the Institute of Transportation Studies at UC Davis (ITS) to retrospectively study automotive safety and environmental regulations. These historical cases will examine how industry and consumers responded to environmental and safety regulations calling for significant, large-scale changes to automotive performance and design.

2. The Greening of the Automobile and Consumer Response

The automotive industry is an extraordinary success story, now accounting for about 6% of our country's GDP, and about a trillion dollars in annual revenue worldwide. Motor vehicles are also recognized as a major source of climate-change emissions. Passenger vehicles and light-duty trucks are responsible for approximately 40 percent of California's climate change emissions

Government regulation of motor vehicles increased in the 1960s, with government-imposed improvements in vehicle safety, pollution, and energy use. The end result of those regulations is vehicles that are far safer, less polluting, and less energy-consuming than they were four decades ago.

Air pollutants have been reduced largely with after-treatment controls and engine air/fuel management, leaving vehicles and their energy system essentially unchanged. The cost of pollution control has been modest, generally less than a thousand dollars extra per vehicle. Vehicle safety has improved substantially at a cost of a few hundred dollars per vehicle through the addition of restraint systems such as seatbelts and airbags. Safety and pollution rules have been especially effective and gained widespread support from the public, and broad acceptance by industry.

Climate change regulations would encourage automakers to apply future improvements in automotive engineering to reducing climate change emissions. The ARB's consumer-oriented modeling will estimate how consumers are likely to respond to these more environmentally friendly new vehicles both in the marketplace and on the road.

3. Modeling Consumer Response to Climate Change Regulations

To estimate consumer response to climate change regulatory scenarios involving changes to vehicle price, greenhouse gas emissions, and/or performance, the ARB has contracted with the Institute of Transportation Studies at UC Davis to develop a model (named CARBITS).

CARBITS is a vehicle transactions model which uses a multinomial logit submodel similar to those used in consumer marketing, urban planning and transportation to simulate the decisions of persons faced with numerous, often competing, choices.

CARBITS simulates the vehicle purchase decisions of 20,000-plus representative California households, predicting new and used vehicle purchases, vehicle sales and scrappage. It updates each household's vehicle holdings every six months, based on the household's demographic changes and transportation needs, and the attributes of available vehicles.

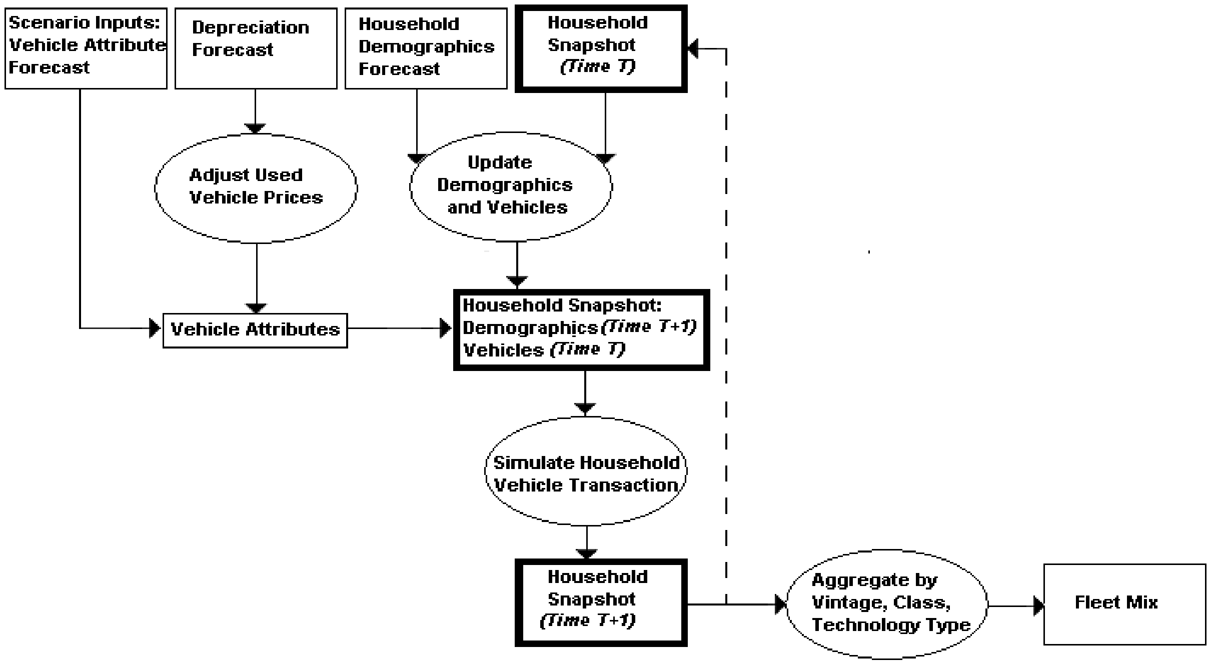
CARBITS makes extensive use of transportation survey results, including ***stated*** and ***revealed*** preference data collected from thousands of California households.[1] The demographic composition, demographic changes, ("forecast"), and decision-making behavior of CARBITS households are based on survey findings. Vehicle transaction probabilities and projections are a function of the interaction of household characteristics with the attributes of available vehicles.

CARBITS outputs will help answer several key questions about the economic impacts of compliance with climate change regulations, including:

- How will vehicle attribute changes caused by climate change regulations affect new vehicle purchases?
- Will these vehicle attribute changes cause the fleet to age, and if so, by how much?
- How will these vehicle attribute changes affect the mix of vehicles (by classification and engine type) in California's non-commercial fleet?
- How much CO2-equivalent reductions will occur as a result of the proposed regulations?

[1] For details about the survey data and how the model uses it, see David Brownstone, David S. Bunch and Kenneth Train, "Joint Mixed Logit Models of Stated and Revealed Preferences for Alternative-fuel Vehicles", Transportation Research B, Volume 34, Issue 5 (June 2000), pp. 315-449. For details about the VMT submodel, see Thomas F. Golob, David S. Bunch and David Brownstone, "A Vehicle Use Forecasting Model Based on Revealed and Stated Vehicle Type Choice and Utilization Data," Journal of Transport Economics and Policy Vol. 31 (1997): 69-92.

Figure 2. CARBITS Flow Chart



The figure above represents CARBITS simulation inputs and outputs (rectangles) and processes (ellipses). The model recalculates outputs every half year. So, for example, a simulation run from 2000 to 2020 includes 40 timesteps.

At the beginning of each timestep, for each of 20,000-plus households, the model starts with:

- Scenario Inputs – the vehicle attributes for that year (for the appropriate combination of classifications, engine types and ages) and fuel prices.
- Household Vehicle Holdings – an inventory of the vehicles owned by each household's members; and,
- Household Demographic Attributes – the demographic characteristics of each household.

During the initial forecast year, household vehicle holdings and demographic attributes are established by survey data.

The CARBITS simulation performs the following steps for each household:

- **Update vehicle attributes.** The model introduces new vehicles into the fleet every year and increases the ages of existing vehicles.
- **Adjust used vehicle prices.** The model calculates updated prices for the used vehicles according to a vehicle depreciation forecast.
- **Update demographics and vehicles.** The model increases the age of all household members. A series of submodels simulates births, deaths, divorces, children leaving home and other demographic transitions. If the

transition results in the creation of a new household, then a submodel divides vehicle holdings among the old and new households.

- **Simulate household vehicle transactions.** The model considers all the possible vehicle transactions for all households.[2] Each household weighs a series of decisions:
  - To transact or not;
  - To add, replace, or drop a vehicle;
    - If add, decide what vehicle class and vintage to purchase;
    - If replace, decide which vehicle to replace, and what to replace it with;
    - If drop, then decide which vehicle to drop and whether to scrap or sell.

  The model calculates probabilities for all possible transactions.[3] The probabilities are based on statistical analysis of the survey data, and take into account the length of time since any previous transaction, as well as the utility of current vehicle holdings. The output is a probability distribution of each household's possible vehicle transactions. Aggregated, these probability distributions yield the statewide forecast values for each timestep. The model then re-sets each household's vehicle holdings for the next timestep.

The ARB will construct plausible climate change "regulation scenarios" by modifying vehicle attribute input to reflect potential automobile industry responses to proposed regulations. A typical scenario might involve changes to price and operating costs for model years 2009 and later. The impact of the proposed regulation shows up as the *difference* between the regulation scenario's output and the baseline (no regulation) scenario's output.

CARBITS' baseline scenario simulates a future in which vehicle attributes have not been affected by climate change regulation. CARBITS' baseline scenario input consists of vehicle attribute data for 13 vehicle classes, each with five engine types, for model years 1975-2020. The table below lists CARBITS data inputs and outputs, including those inputs (marked with asterisks in the table below) that are adjusted to reflect the indirect impact of greenhouse gas reduction regulatory scenarios on various vehicle attributes.

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[2] David Brownstone, David S. Bunch, Thomas F. Golob, and Weiping Ren, "A transactions choice model for forecasting demand for alternative-fuel vehicles," **Research in Transportation Economics**, Vol. 4, 87-129, 1996.
[3] David Brownstone, David S. Bunch and Kenneth Train, "Joint Mixed Logit Models of Stated and Revealed Preferences for Alternative-fuel Vehicles", Transportation Research B, Volume 34, Issue 5 (June 2000), pp. 315-449.

CARBITS Inputs and Outputs

	Model Inputs
New Vehicle Price*	$
Fuel Economy *	Miles per gallon ratings for all vehicles
0-30 Acceleration*	A proxy for vehicle performance
Depreciation Forecast	For used vehicle pricing
Fuel Price	Per gallon, gasoline and diesel
Household Vehicle Snapshot	Vehicle holdings of each household, based on survey data
Household Demographic Forecast	Composition of household and predicted changes, also based on survey data
	Model Outputs
Total Vehicle Stock	# vehicles by class, age, and technology type for each forecast year
Vehicle Transactions	Ownership changes, including new and used vehicles

Looking at the differences between the baseline scenario outcomes and regulation scenario outcomes serves two purposes: it literally provides an estimate of differences due to the regulation, and, to the extent that CARBITS has systemic biases, they are largely nullified by focusing on the difference between two sets of scenario outputs. The outcomes of the CARBITS analysis will determine how the ARB's macroeconomic scenario should be defined to account for climate change regulations.

4. Rebound Effect Assessment

The Rebound Effect is commonly understood as drivers' tendency to react to reduced operating costs with an increase in driving.

The ARB's climate change regulations, which would take effect in with MY 2009 vehicles, are likely to result in reduced operating costs for vehicles and increased vehicle purchase price. Because of the reduced operating costs, there may be a rebound effect, i.e. consumers may drive more. However, the other factors specific to the climate change regulations, such as the increase in vehicle purchase price and California-specific economic factors, may modify the extent of the rebound effect. There are no existing studies that quantify a California-specific rebound effect in the future and take into account reduced operating costs and increased vehicle purchase price. Therefore, ARB staff will be working with experts in the field, including economists at U.C. Irvine, to evaluate the extent of the rebound effect given these parameters.

The ARB's investigation will:

- Develop a theoretical framework embedding the rebound effect;

- Review current knowledge about the rebound effect and assess its relevance for climate change regulations;
- Identify and assess data sets relevant for climate change regulations; and
- Estimate empirical models on data relevant to climate change regulations.

A theoretical model will identify the main variables – and the interaction between those variables – determining the rebound effect. This model will serve as a guideline for a structured review of existing studies and for the selection of a dataset and an estimation procedure.

Existing theoretical and empirical methodologies will be critiqued to determine which results are most well-supported. Special attention will be paid to determining whether the rebound effect depends on characteristics that vary by location, time period, and vehicle purchase price relative to operating cost in order to assess the relevance of past estimates for climate change regulations.

The ARB will carefully evaluate appropriate datasets, including time-series and cross-sectional data, and estimates that best reflect the effects of climate change regulations will be developed to the extent possible, providing direct measures of the extent of the rebound effect under various circumstances.

5. Industry Response to Technological Change

In cooperation with U.C. Davis investigators, staff is assessing the automobile industry's response to technological challenges imposed by previous state and federal regulations. The study is based on an examination of specific cases, such as air bags or emission control devices. Each case will retrospectively examine:

- The regulatory context of the technological challenge, and industry's posture concerning legislated improvements;

- The technology developed in response to a regulatory challenge and its subsequent evolution;

- The changing cost of these new devices as production volumes increased;

- How device costs affected pricing, packaging and sales; and

- How development and integration of these new automotive technologies impacted the economy: e.g. employment, business creation and expansion, competition.

6. Modeling the Impact of Climate Change Regulations on the State Economy

The overall impact of all direct and indirect economic effects that may result from climate change regulations will be estimated using a computable general equilibrium (CGE) model of the California economy. A CGE model simulates economic relationships in a market economy where prices and production adjust in response to changes caused by regulations to re-establish equilibrium in markets for all goods and services and factors of production (labor and capital).

The CGE model that will be used for this analysis is a modified version of the California Department of Finance's Dynamic Revenue Analysis Model (DRAM).[4] The modified model is called Environmental-DRAM (E-DRAM).[5] E-DRAM describes the relationships among California's producers, consumers, government, and the rest of the world. Changes to the model enable it to assess the economic impacts of large-scale environmental regulations. Economic impacts will be estimated in terms of changes in the State's output, personal income, and employment.

To model the relationships among California's producers, consumers, government, and the rest of the world, E-DRAM includes over 1,000 equations designed to capture the interactions between:

- 29 industry sectors,
- Two factor sectors (labor and capital),
- Nine consumer goods sectors
- Seven household sectors (classified by income level),
- The investment sector,
- 45 government sectors (8 federal, 21 State, and 8 local), and,
- The rest of the world.

Data for the industrial sectors are based on the Census of Business, a survey of companies conducted in the U.S. every five years by the U.S. Department of Commerce's Bureau of Economic Analysis. An impact analysis program (IMPLAN) converts national data to California data by down-sizing national-level industrial data.

E-DRAM aggregates households in much the same way as it aggregates firms, categorizing them by their taxable income. The model includes seven such categories, each one corresponding to a California personal income tax marginal tax rate (0, 1, 2, 4, 6, 8, and 9.3 percent). Income for the "one-percent" household category, for example, is calculated by adding up the income from all households in the one-percent bracket.

[4] For a complete description of DRAM, see Peter Berck, E. Golan and B. Smith, "Dynamic Revenue Analysis for California", California Department of Finance, Summer 1996.
[5] Berck, Peter, "Developing a Methodology for Assessing the Economic Impacts of Large Scale Environmental Regulations", Prepared for California Air Resources Board, February 2000.

Similarly, the expenditure of the one-percent household on transportation goods, for example, is calculated by adding up all expenditures on transportation goods by these households. The total expenditure on agricultural goods is found by adding the expenditure of all households together.

In E-DRAM, firms and households relate through factor markets and goods-and-services markets. Firms sell goods and services to households on the good-and services markets, while households sell labor and capital services to firms on the factor markets. The model establishes a clearing price for each factor and goods-and-services market. Equilibrium in the factor markets and the goods-and-services markets is achieved when prices adjust in response to changes caused by regulations to equate quantities supplied and demanded in all markets.

The ARB will interpret E-DRAM outputs to satisfy AB 1493's requirements for macroeconomic impact assessment, including:

- creation of new California businesses;
- expansion or elimination of existing California businesses;
- impact on interstate competitiveness of California businesses;
- impact on auto workers in the state; and,
- ability of the State to maintain and attract businesses.